Ensemble Seasonal Forecasting Initialized from Multiple Ocean Initialization with CFSv2

Jieshun Zhu[1], *Bohua Huang*[1,2], *Lary Marx*[1], *James L. Kinter III*[1,2]
Magdalena A Balmaseda[3], *Rong-Hua Zhang*[4], *and Zeng-Zhen Hu*[5]

[1]*Center for Ocean-Land-Atmosphere Studies (COLA)*
[2]*Department of Atmospheric, Oceanic, and Earth Sciences*
George Mason University (GMU)
[3] *European Centre for Medium-Range Weather Forecasts (ECMWF)*
[4] *Earth System Science Interdisciplinary Center/*
University of Maryland, College Park (ESSIC/UMD)
[5]*Climate Prediction Center/*
National Centers for Environmental Prediction/NOAA (CPC/NCEP/NOAA)

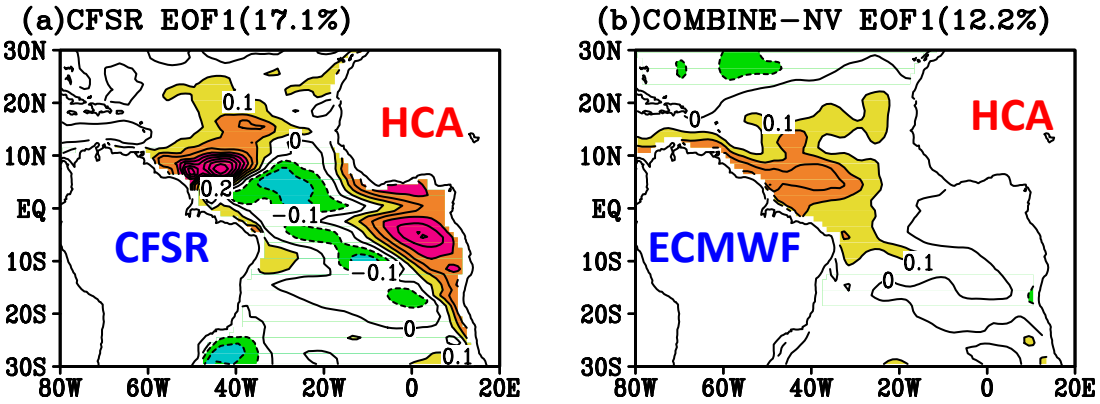
Acknowledgment: ***Prof. J. Shukla (COLA/GMU)***

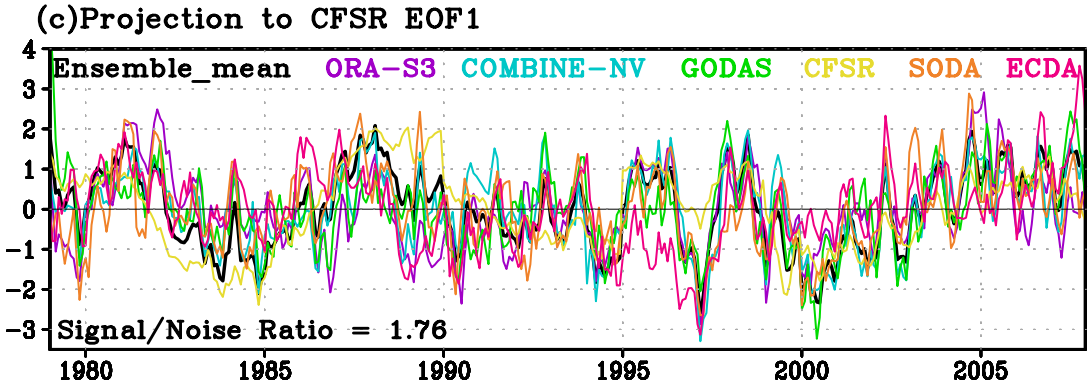
Multiple Ocean Analyses

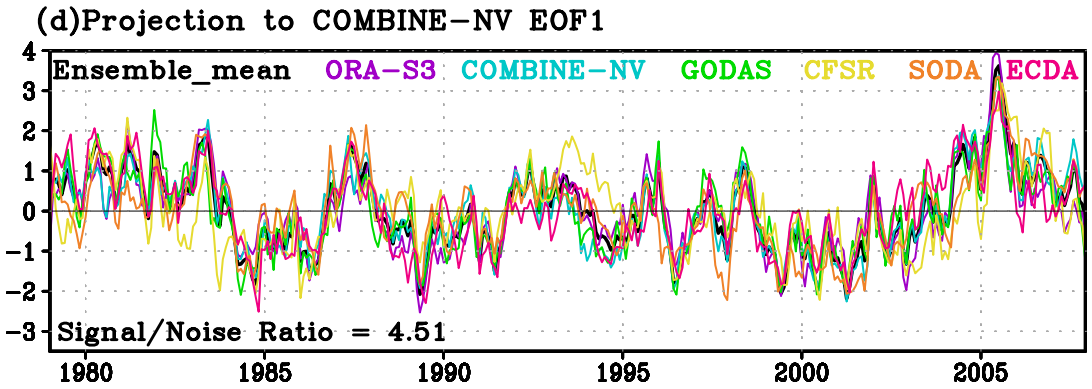
- **ORA-S3, ECMWF (Balmaseda et al. 2008)**
- **COMBINE-NV, ECMWF (Balmaseda et al. 2010)**
- **ORA-S4, ECMWF (Balmaseda, personal communication)**
- **GODAS, NCEP (Behringer 2005)**
- **CFSR, NCEP (Saha et al. 2010)**
- **SODA2.1.6, UM/TAMU (Carton and Giese 2008)**
- **ECDA, GFDL (Zhang et al. 2007)**
- ……

Different model systems
Different assimilation schemes
Slightly different observational inputs

Why Multiple Ocean Initialization?







Heat content anomaly (HCA) from ODA analyses shows high uncertainty

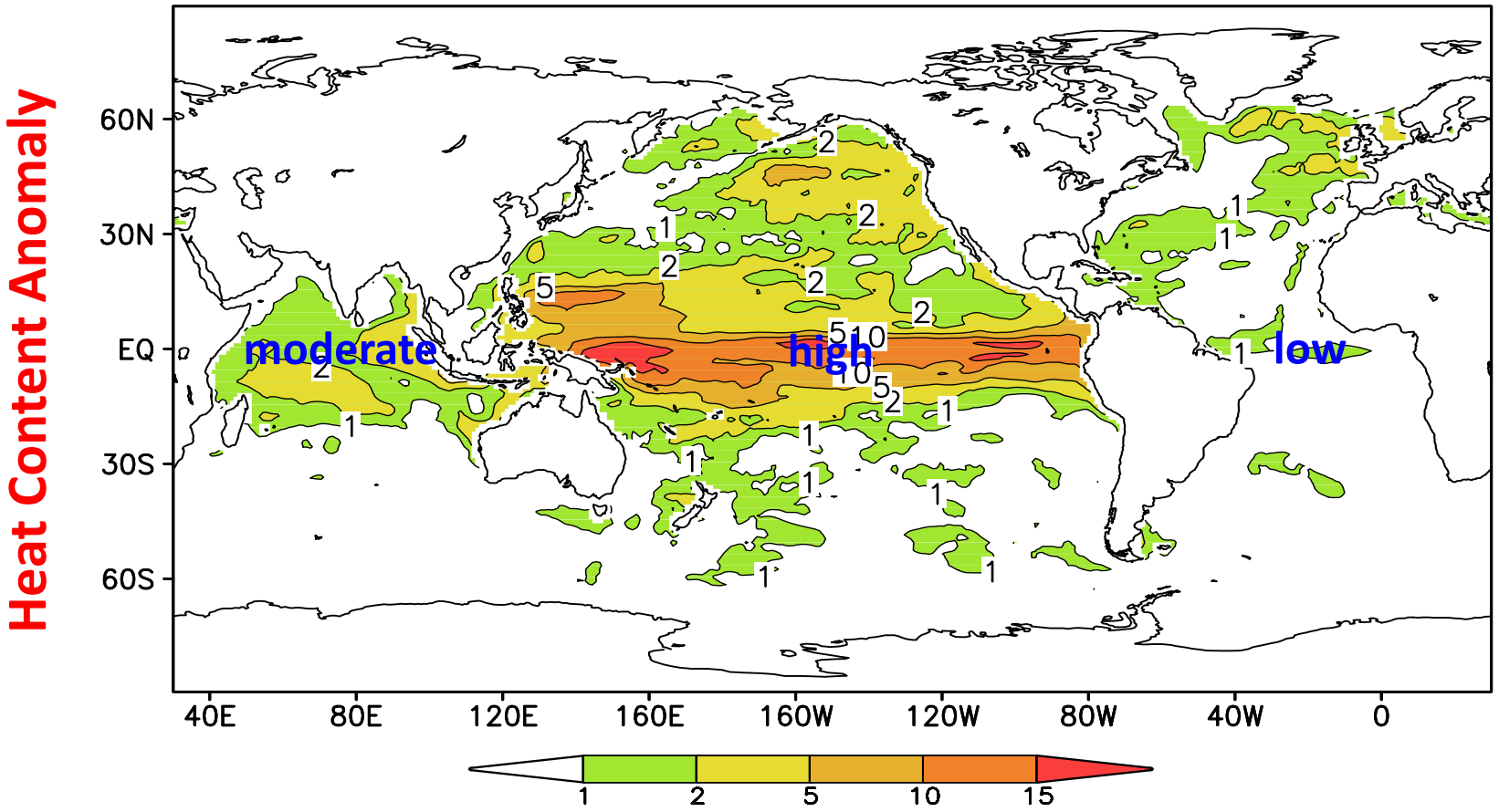
Example:

Tropical Atlantic

1st EOF modes from different analyses give different patterns

Projection spread is large among analyses

$$Signal/Noise\ Ratio = \frac{Var(Ensemble\ Mean)}{Var(Intra\_Ensemble\ Deviation)}$$

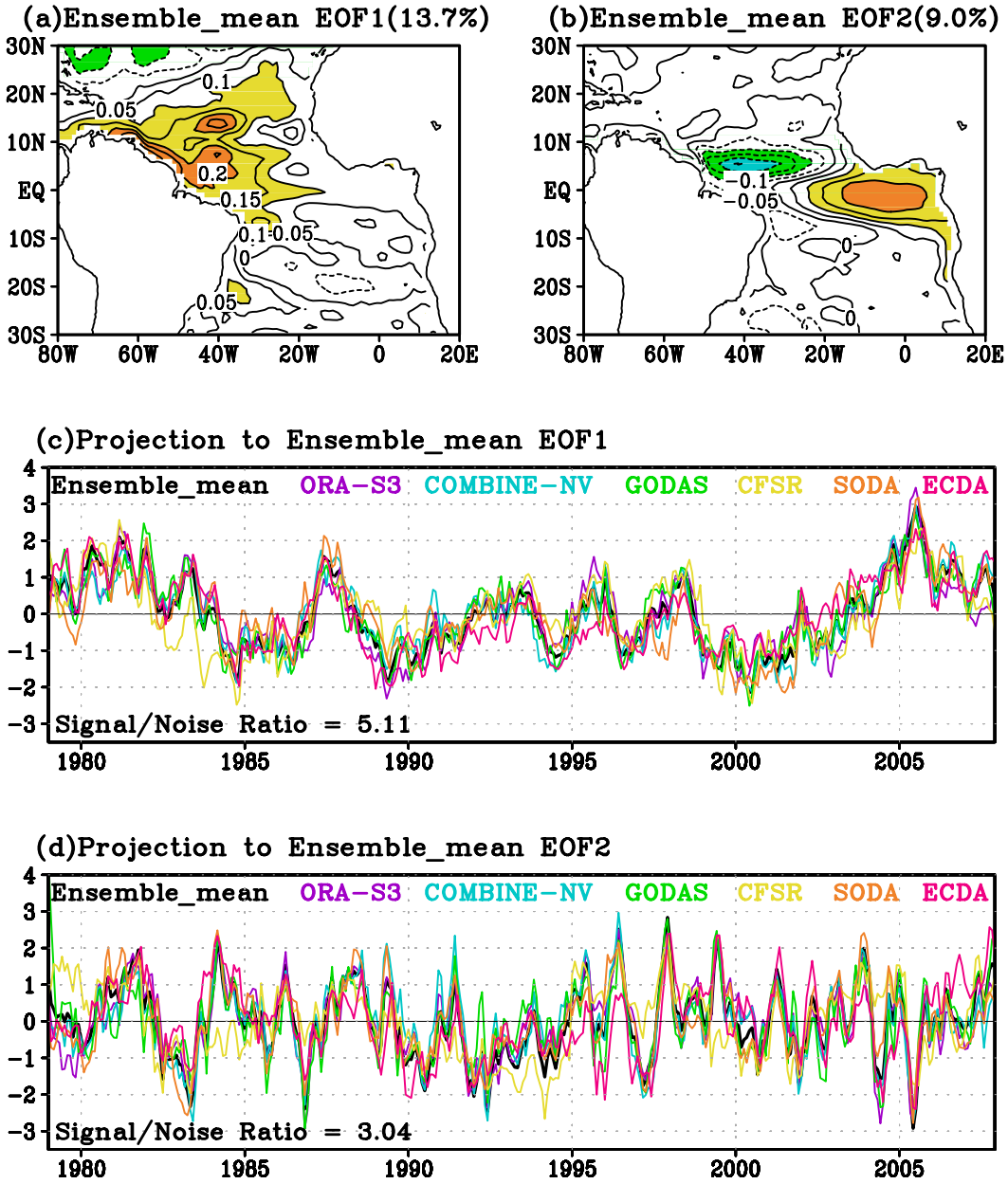


ODA Heat Content Uncertainty (1979-2007)

DATA SOURCE

ECMWF:	ORA-S3, COMBINE-NV
NCEP:	GODAS, CFSR
UM/TAMU:	SODA
GFDL :	ECDA

Heat Content Anomaly



Ensemble average reduces noise effectively

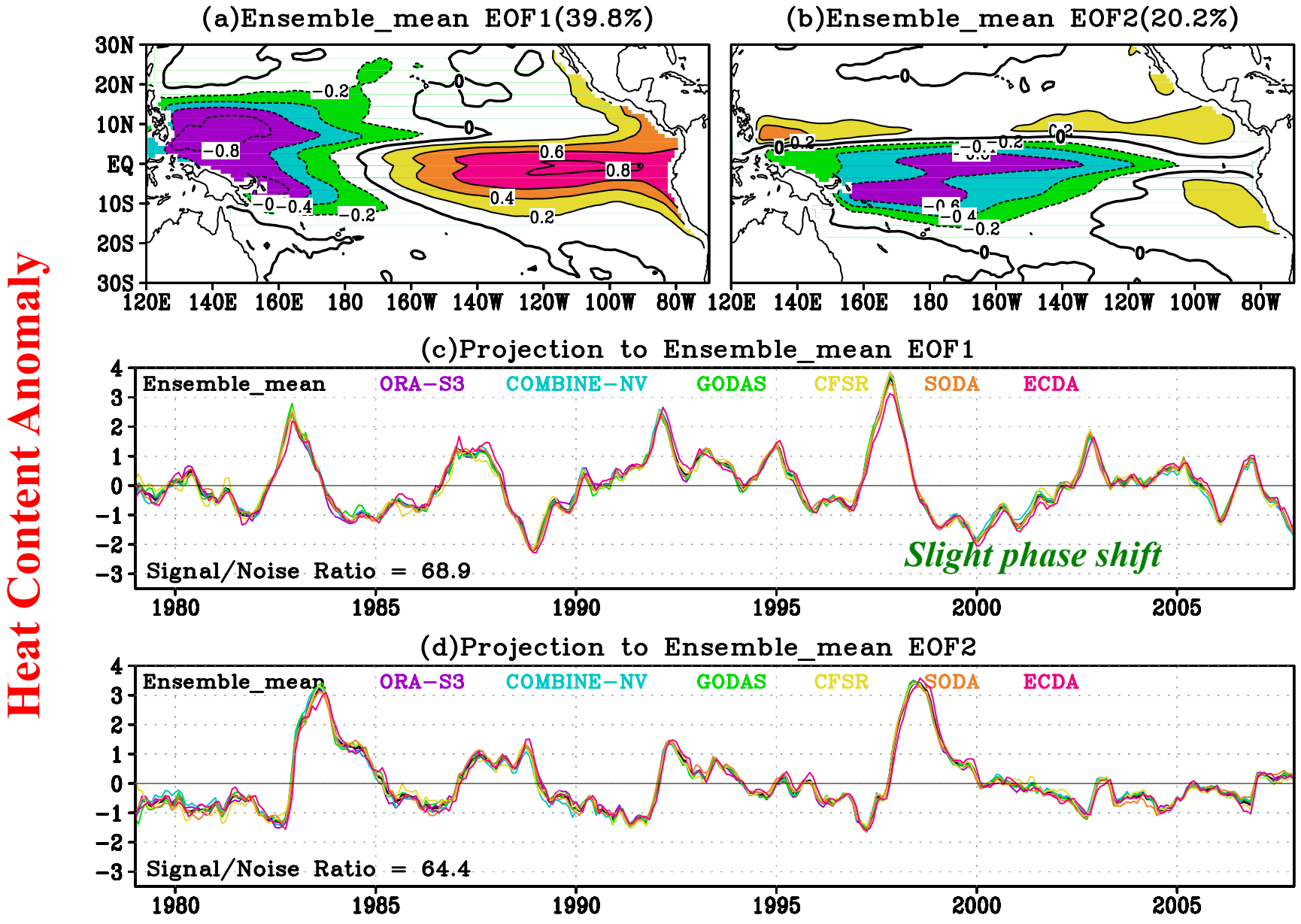
Leading EOF patterns become physically meaningful

S/N ratio improves significantly

Signal exists in all analyses (masked by high internal noise)

Zhu et al. (*Clim. Dyn.*, in press)

Uncertainty is relatively low in Tropical Pacific



Is ocean uncertainty negligible for ENSO prediction?

Scientific Questions

- *What are the effects of uncertainty in upper ocean heat content on seasonal-to-interannual (SI) prediction?*

- *Will ensemble predictions initialized with multiple ocean analyses improve SI predictive skill?*

Experiment Design

12-month hindcasts initialized in April

- **Forecast Model: NCEP CFS version 2**

1) Atmosphere (GFS) T126, L64

2) Ocean (MOM4) 0.5°x0.5° (0.25° lat, 10°S-10°N), L40

- **Multi-Ocean Initialization Experiments (1979-2007)**

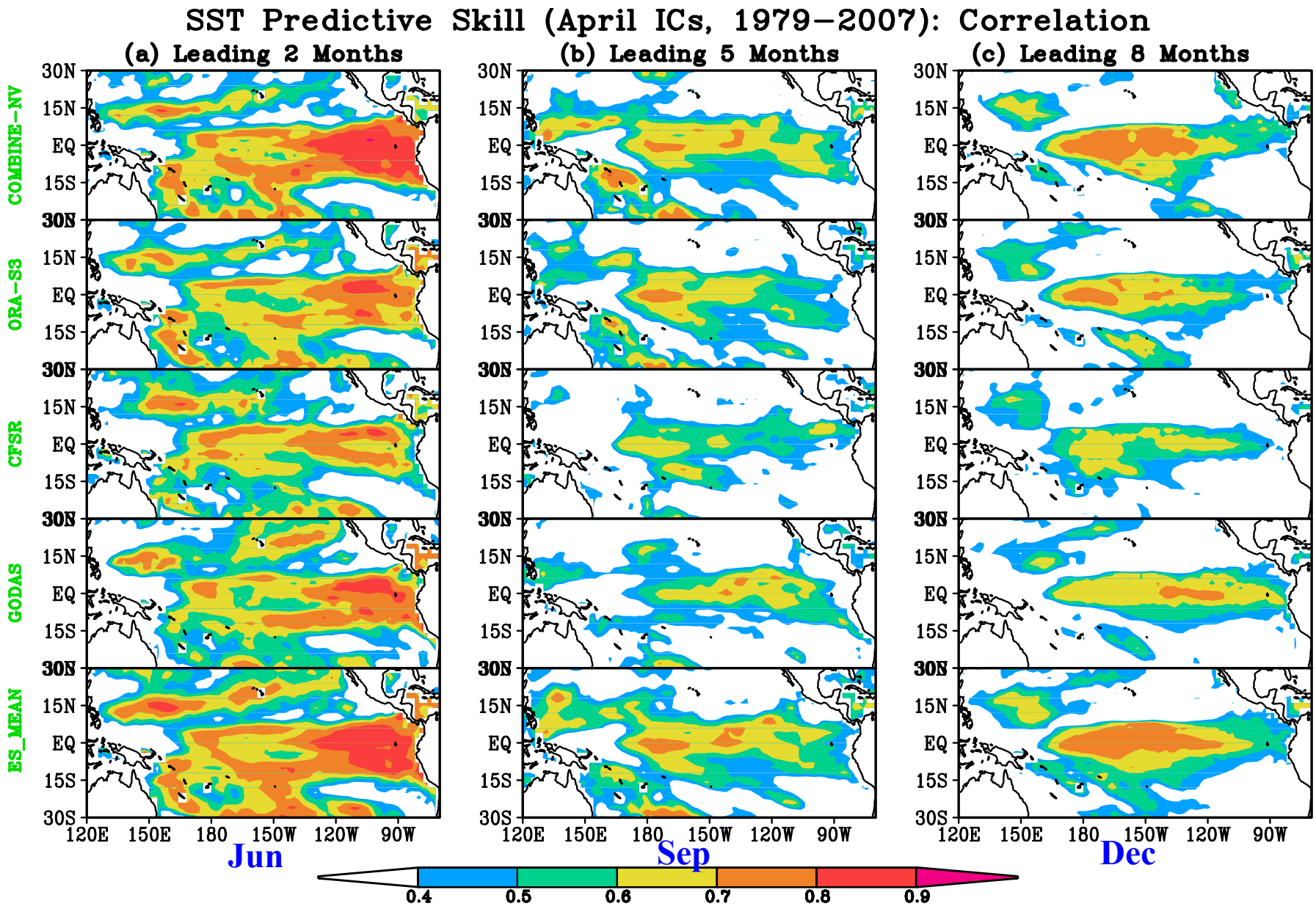
1) Ocean initial state (OIC): **Monthly means** from **COMBINE-NV**, **ORA-S3**, **CFSR**, **GODAS**
2) Anomaly initialization in OIC
3) Perturbed Atmosphere-land IC (4-member with each OIC, Apr. 1-4, CFSR)

- **Additional Hindcast Experiments**

1) AVEoci --- Average OIC of **COMBINE-NV**, **ORA-S3**, **CFSR**, **GODAS**

2) ORA-S4 ---**instantaneous** OICs from **ORA-S4** (1982-2009) with **full** Initialization

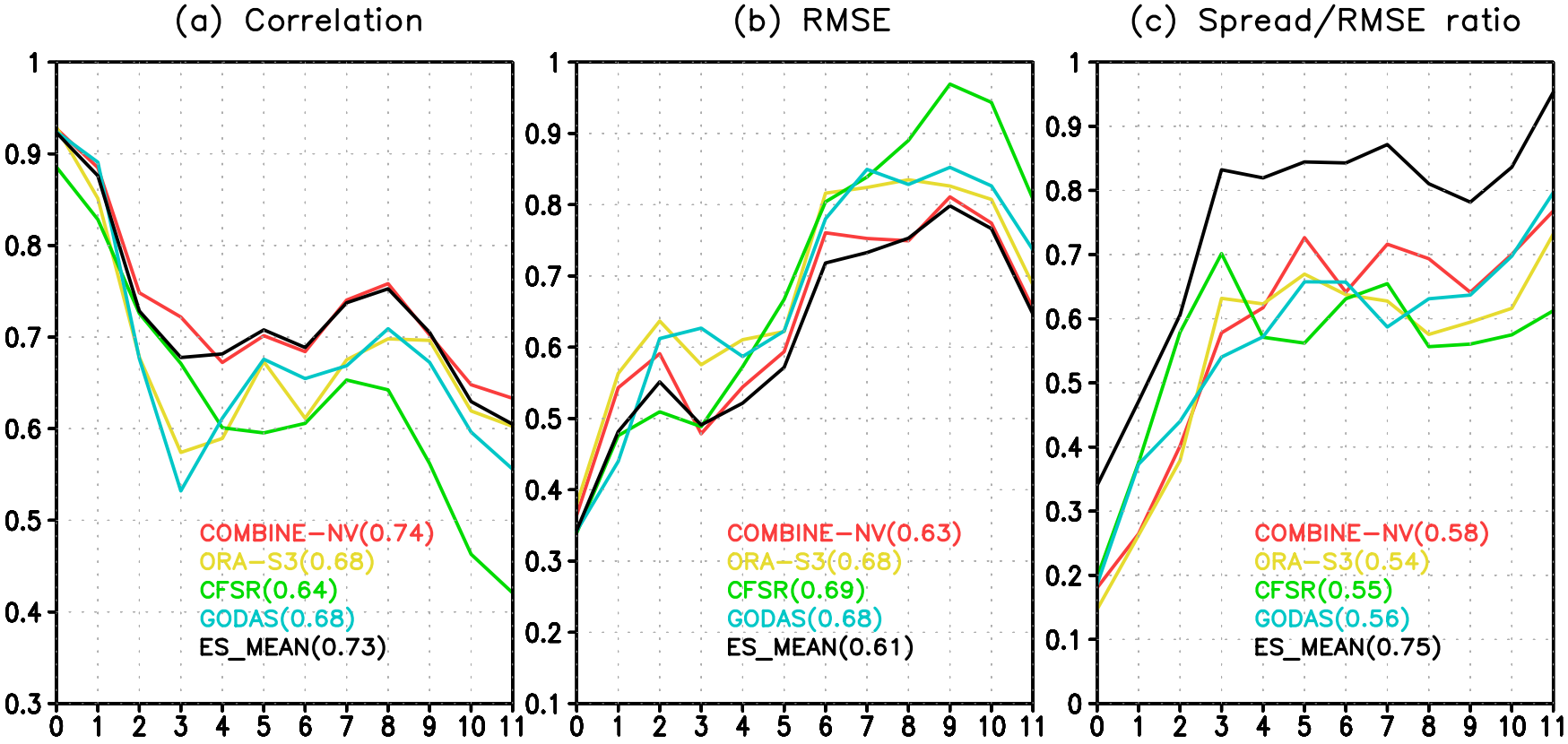
3) CFS Reanalysis and Reforecast (**CFSRR, Provided by NCEP**, 9-month, 24-member, 1982-2009)



Zhu et al. (*GRL.*, in press)

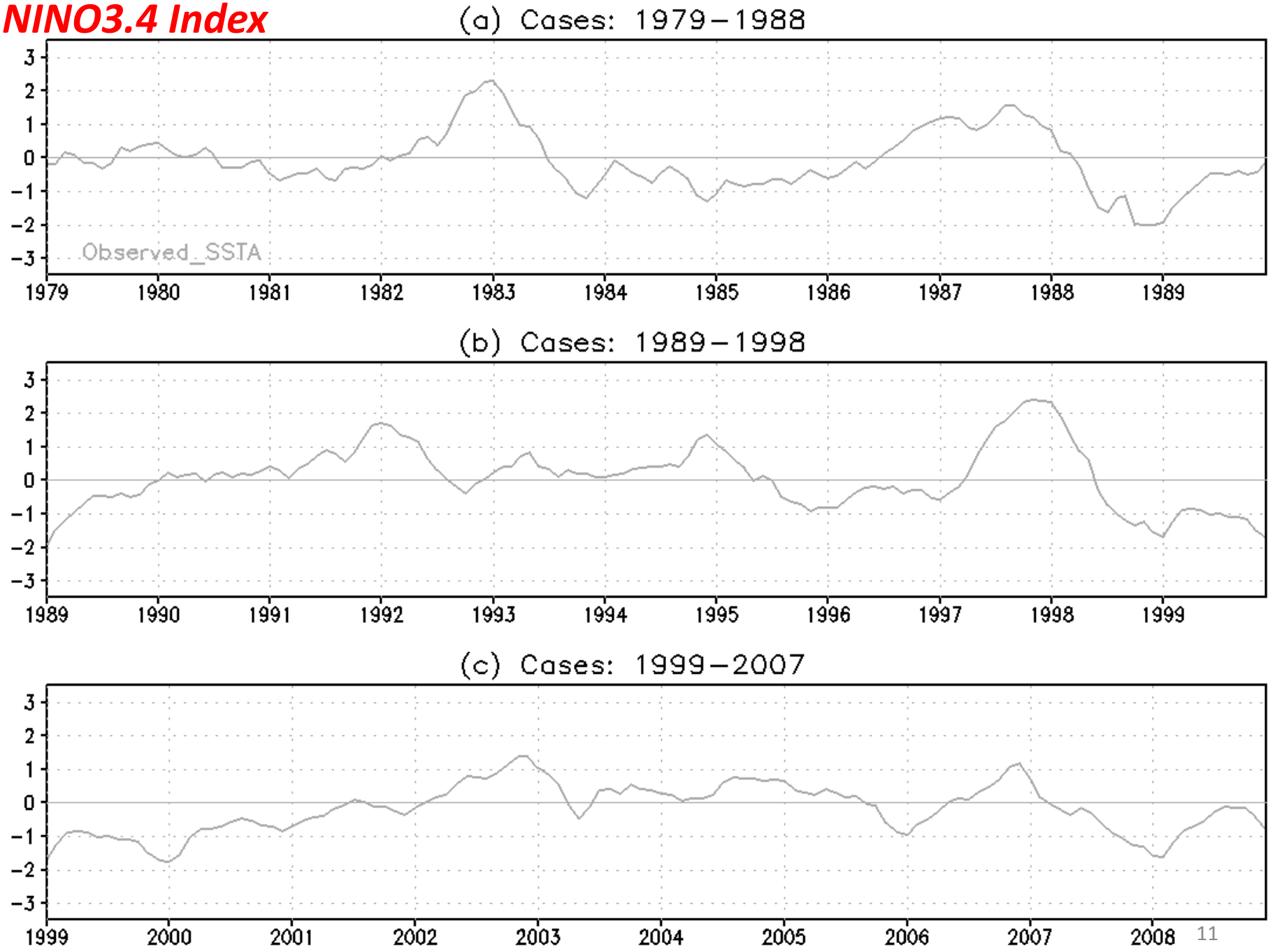
Prediction skill of the Nino3.4 is sensitive to OICs

(April ICs: 1979-2007)

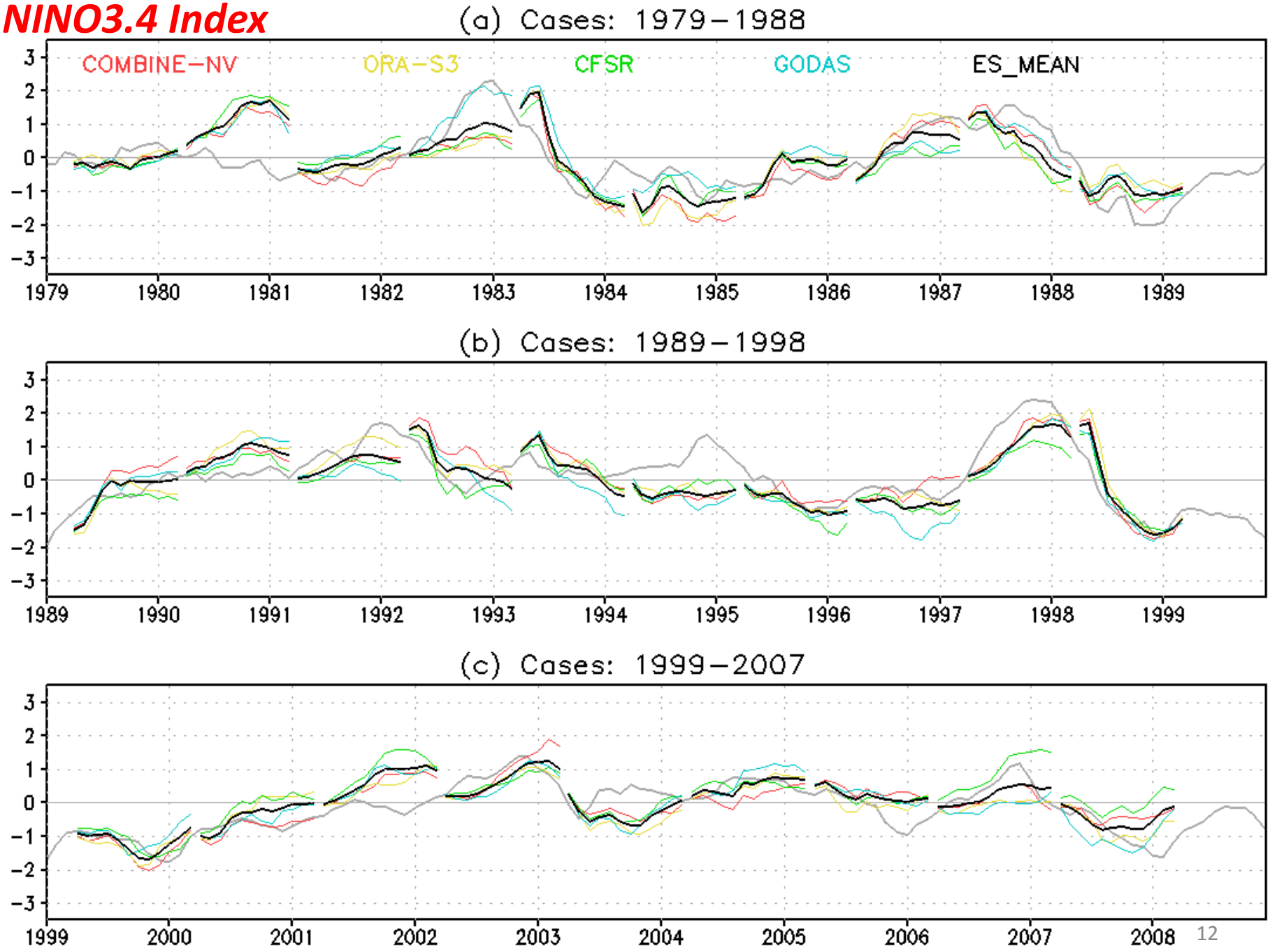


- ***Predictive skills of individual OICs have substantial differences***
- ***ES_Mean is comparable to the best of individual predictions***
- ***Perturbing OICs gives a better ensemble spread than perturbing AICs only***

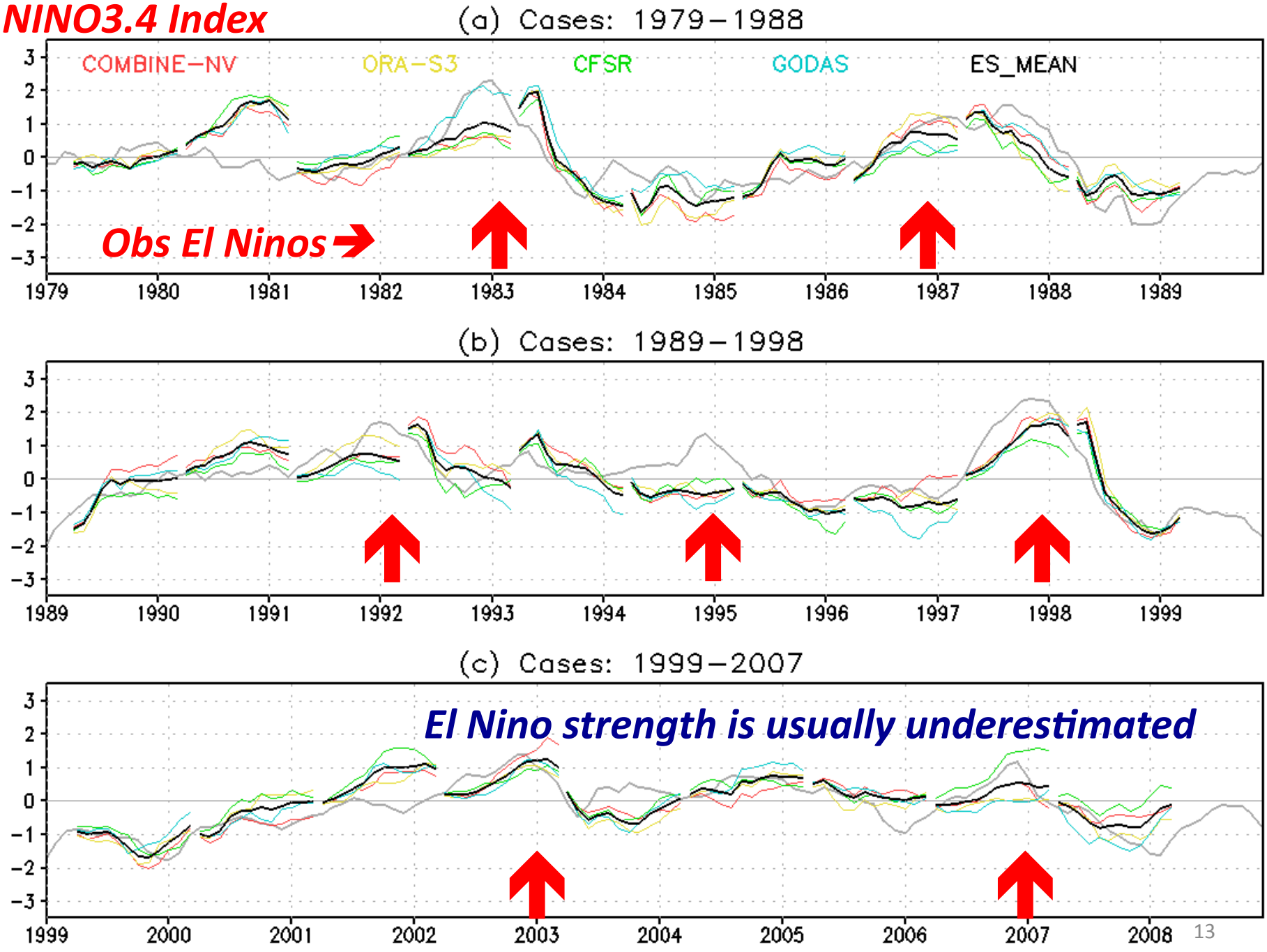
NINO3.4 Index



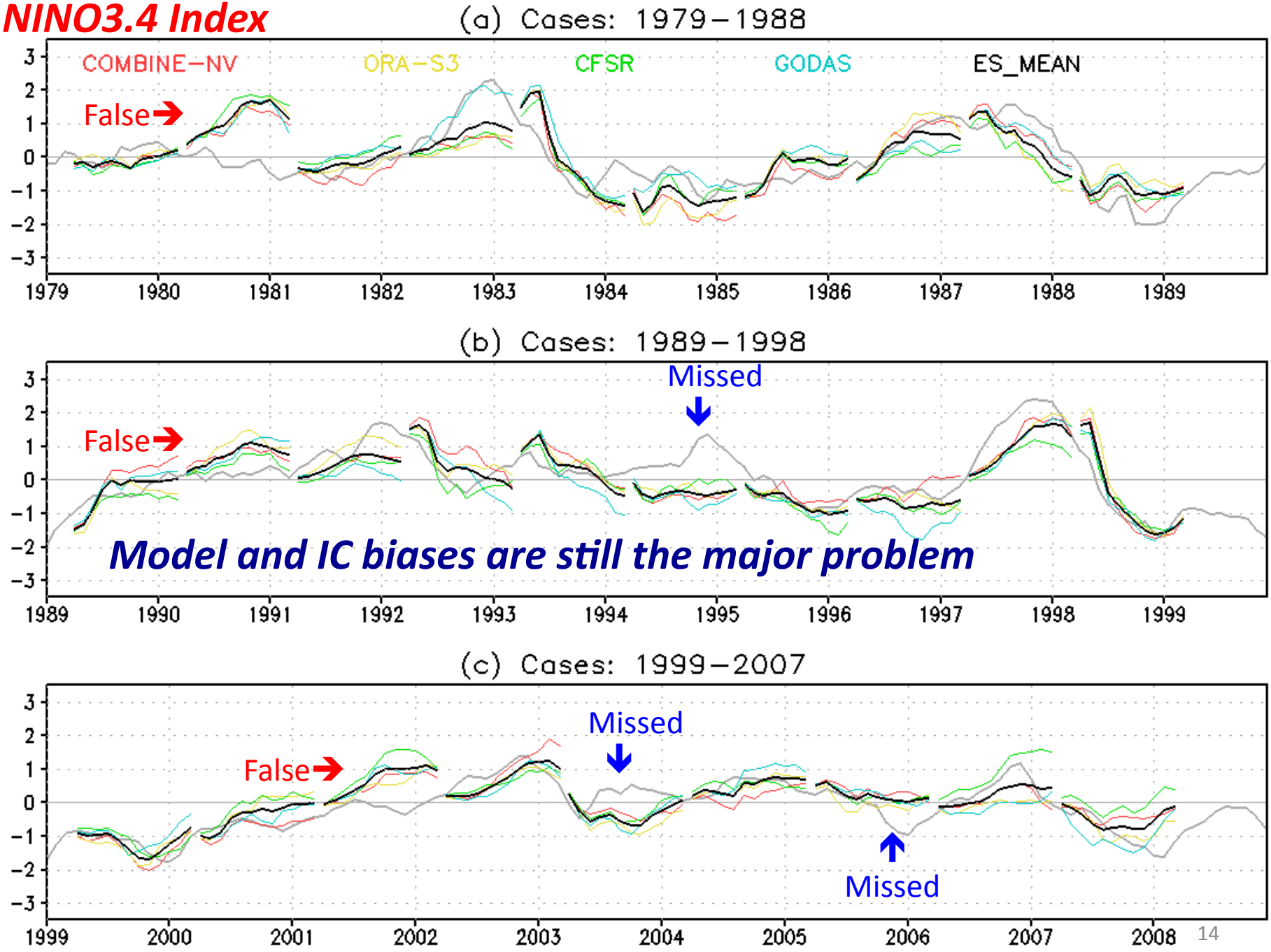
NINO3.4 Index



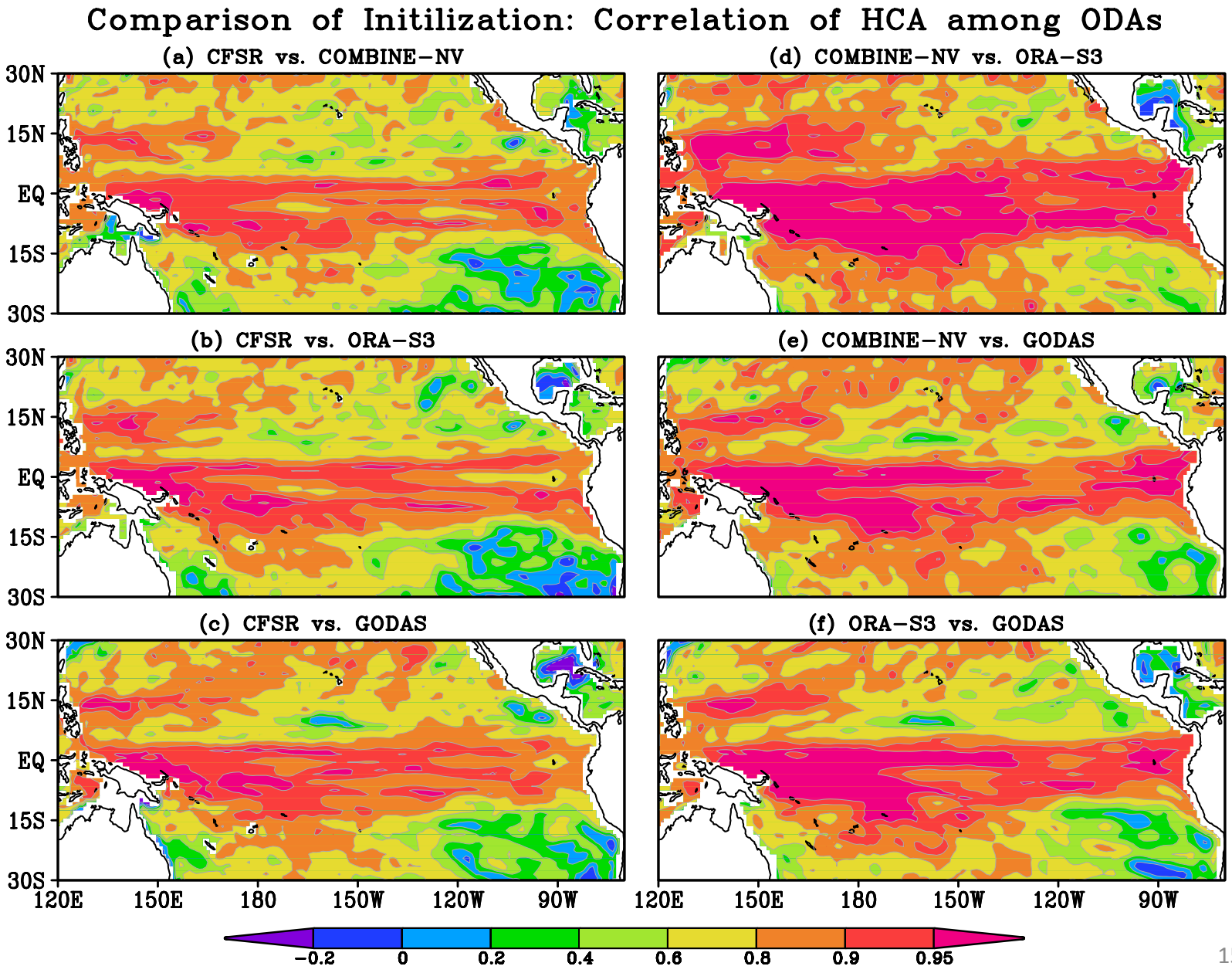
NINO3.4 Index



NINO3.4 Index



CFSR initial states seem slightly different from others



Ensemble Mean OIC
vs
Ensemble Ocean Prediction

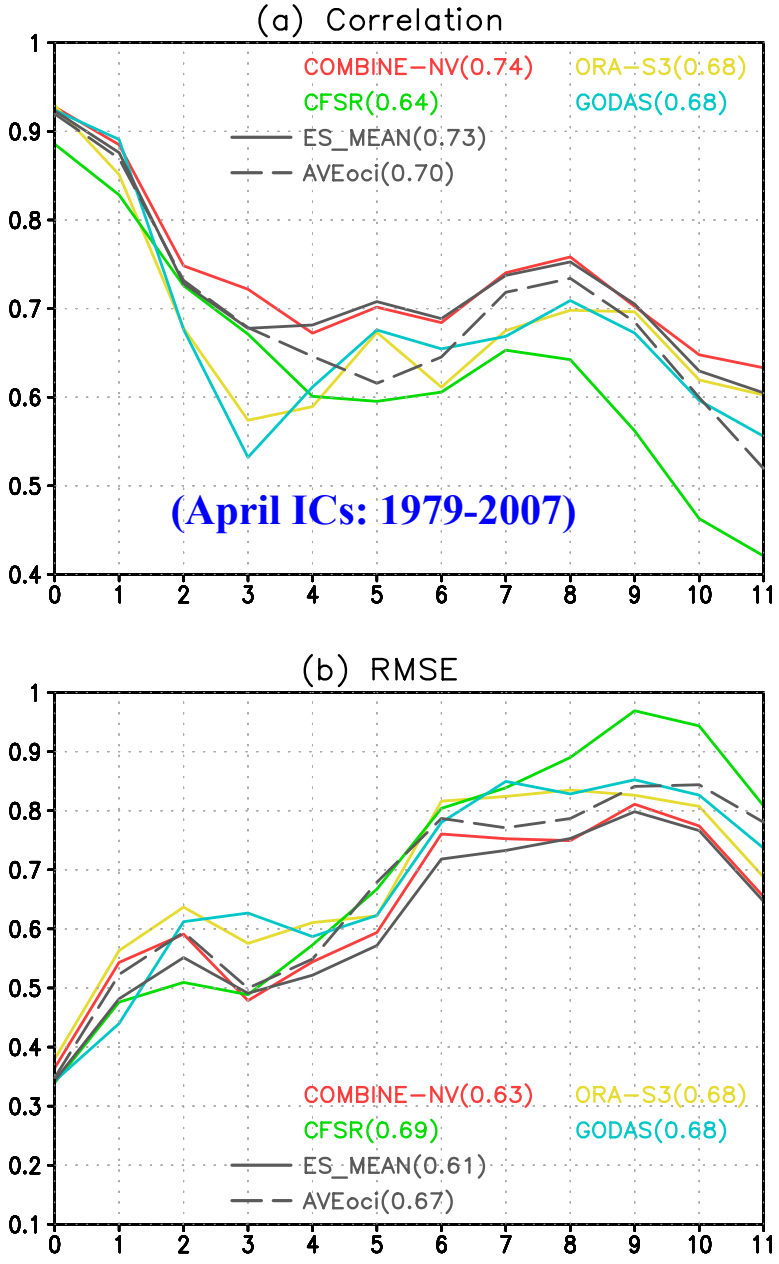
AVEoci Features

1) Ensemble mean **OIC** from
   COMBINE-NV ORA-S3
   CFSR GODAS

2) **Anomaly** Initialization

3) **4** ensemble members

Ensemble ocean prediction is superior to ensemble mean OIC



NINO3.4 Prediction Skill

Q1: Does anomaly initialization help?

Maybe

Q2: Does monthly OIC lower skill?

No

CFSRR (NCEP) vs. **CFSR (COLA)**

Differences in Initialization

1) Full vs. Anomaly

2) Instantaneous vs. Monthly

3) Ensemble sizes: 24 vs. 4

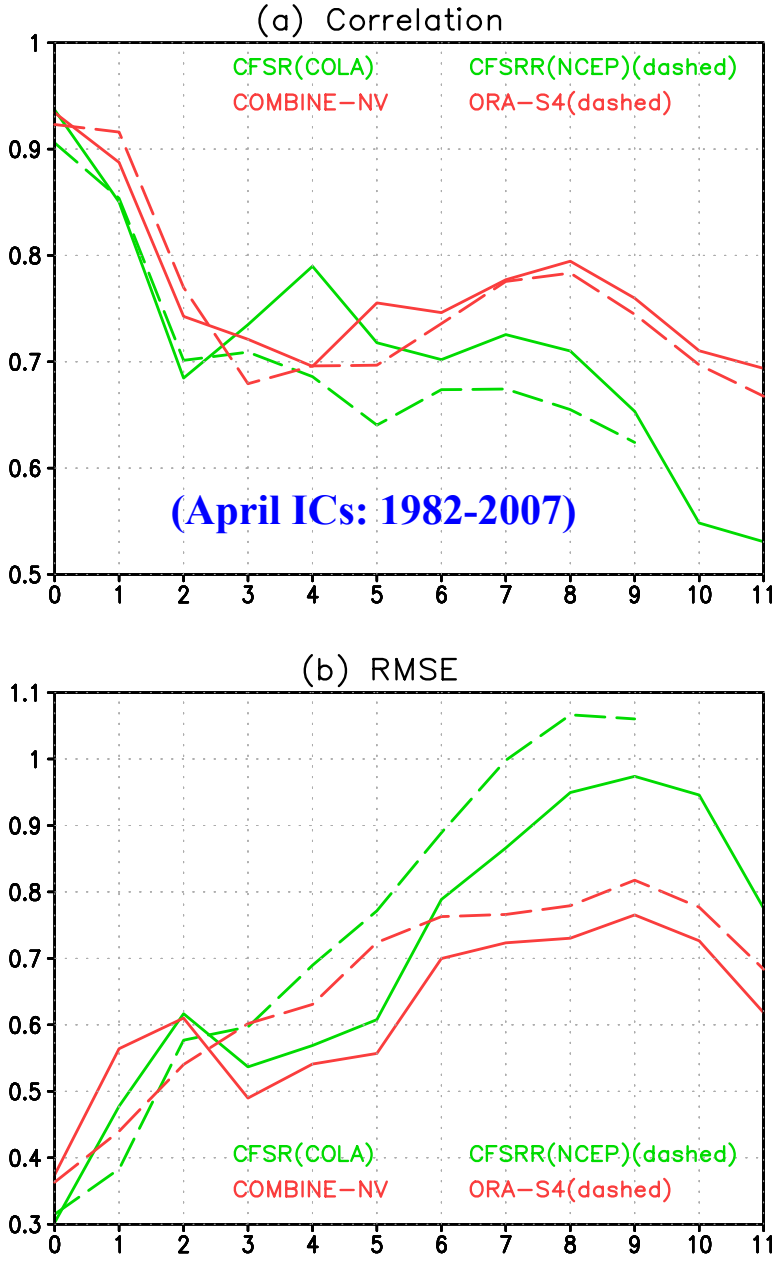
ORA-S4 vs. **COMBINE-NV**

Differences in Initialization

1) Full vs. Anomaly

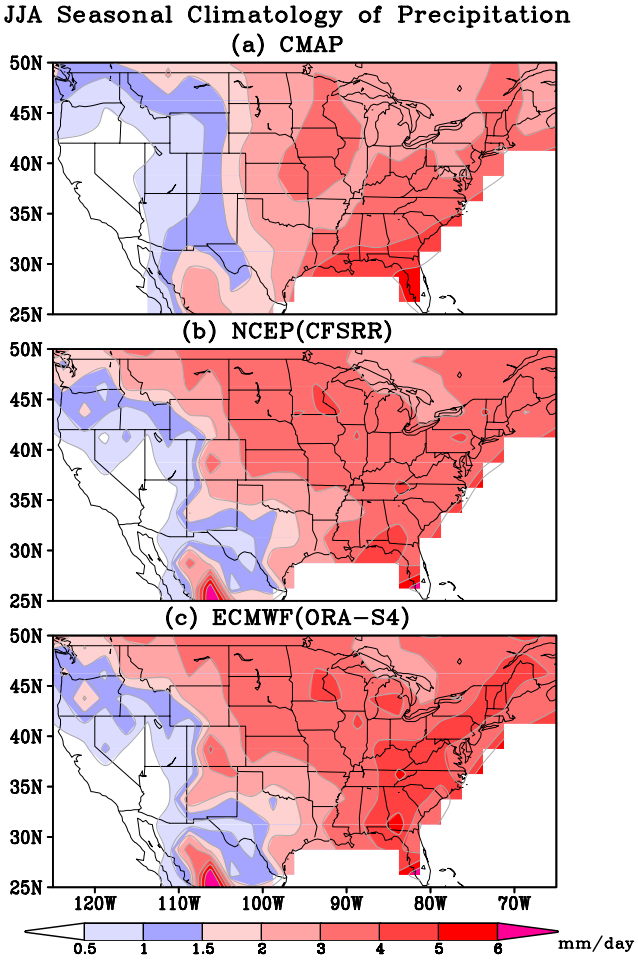
2) Instantaneous vs. Monthly

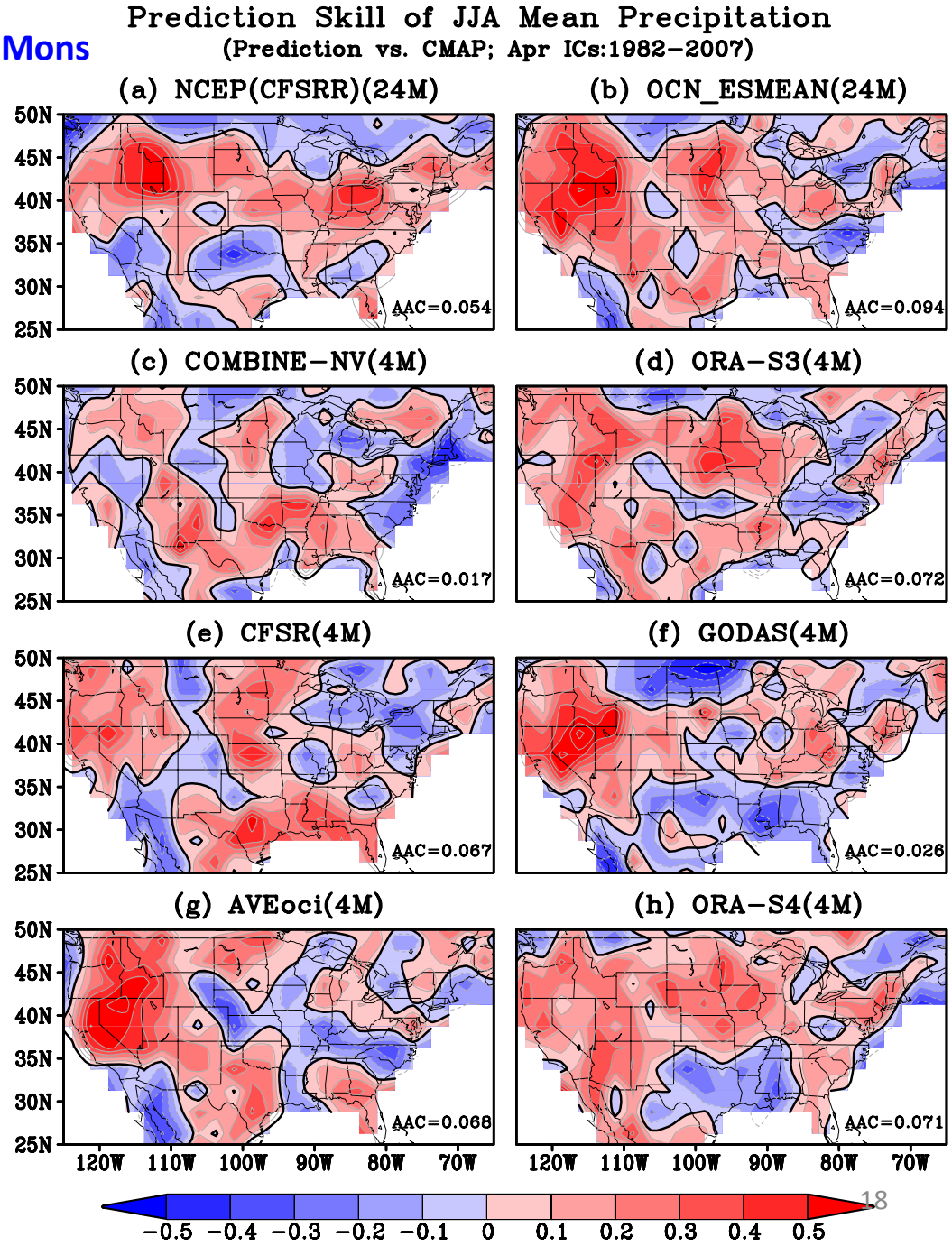
3) ORA-S4 is more updated



NINO3.4 Prediction Skill

LD=2-4 Mons

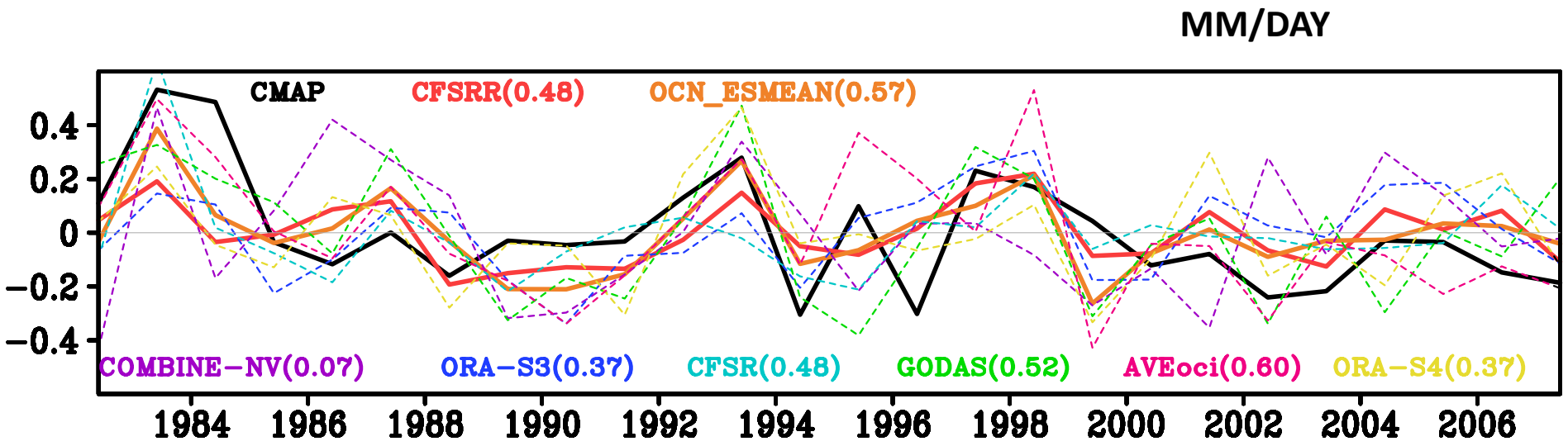


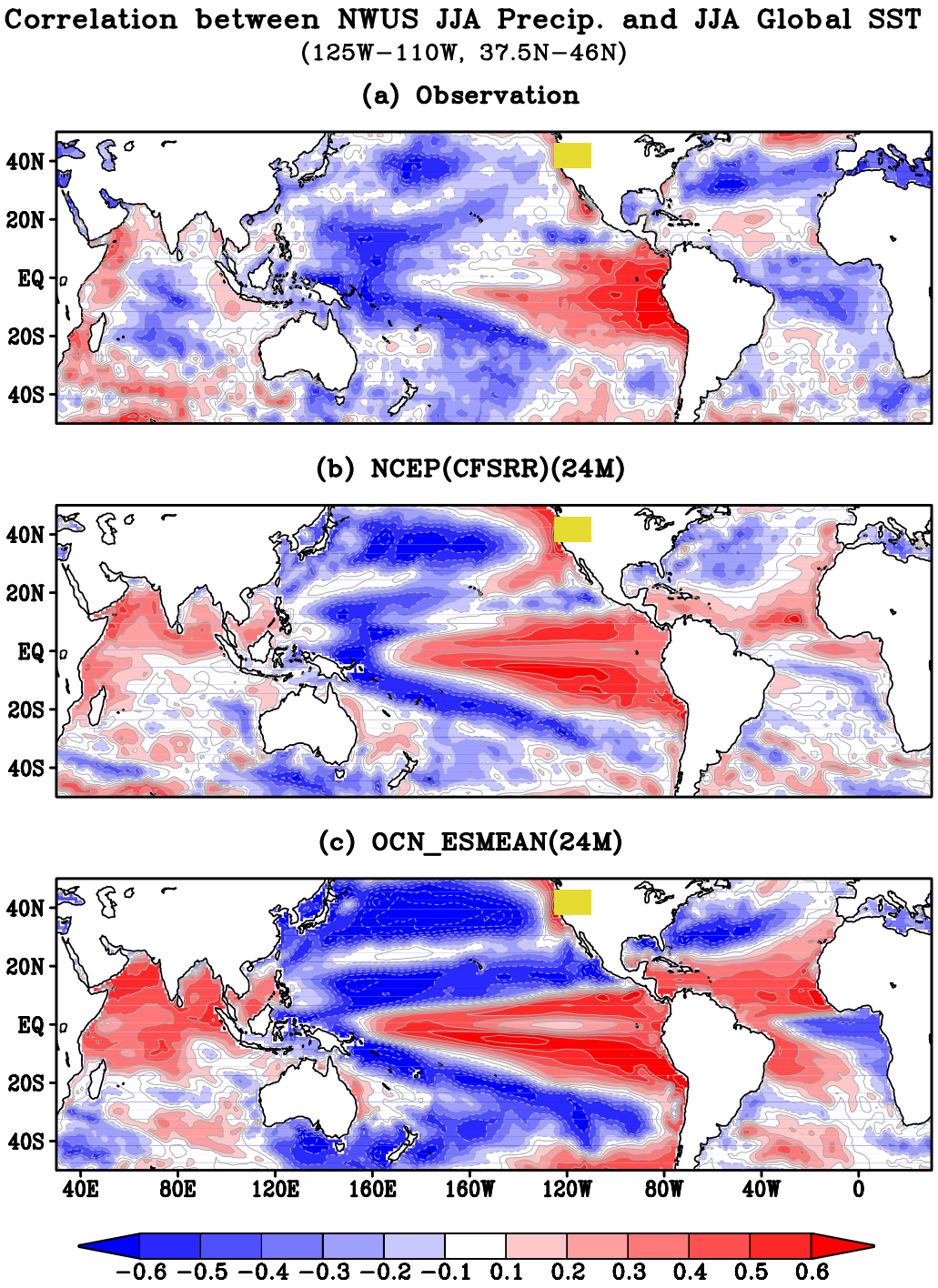


Model shows some skill in the northwestern US

Time Series of JJA Mean Precipitation

NW US (125W-110W, 37.5N-46N)





Correlation with SSTA in JJA

1) The enhanced precipitation is associated with ENSO and PDO

2) OCN_ESMEAN overestimates the correlations with Indian and Atlantic Oceans; CFSRR seems much better.

Summary

- **There is considerable uncertainty in upper ocean heat content anomalies from different analyses**
- **OIC uncertainty causes a noticeable spread in ENSO prediction**
- **Multiple ocean initialization provides more reliable SST prediction in tropical Pacific Ocean**
- **There is no substantial difference between full and anomaly initialization**
- **Predictability of northwestern US precipitation is mainly due to the ENSO-PDO effect**